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INFORMATION ON HUMAN EXPOSURE TO RADIOFREQUENCY FIELDS FROM CELLULAR RADIO TRANSMITTERS

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(1) Cellular base stations

Radiofrequencies constitute part of the overall electromagnetic spectrum. Cellular communications systems use frequencies in the 800-900 megahertz (MHz) portion of the radiofrequency (RF) spectrum (frequencies formerly used for UHF-TV broadcasting). Primary antennas for cellular transmissions are usually located on towers, water tanks and other elevated structures including rooftops and the sides of buildings. The combination of antennas and associated electronic equipment is referred to as a "cellular base station" or "cell site." Typical heights for cellular base station towers or structures are 50-200 feet. A typical base station utilizes either several "omnidirectional" antennas that look like poles or whips, 10 to 15 feet in length, or a number of "sector" antennas that look like rectangular panels. The dimensions of a sector antenna are typically 1 foot by 4 feet. Sector antennas are usually arranged in three groups of three with one antenna in each group used to transmit signals to mobile units (cellular car phones or hand-held cellular telephones). The other two antennas in each group are used to receive signals from mobile units. Similarly, when omnidirectional antennas are used, some transmit and some only receive signals.

The Federal Communications Commission (FCC) authorizes a "wire-line" and "non wire-line" carrier in each service area. The total RF power that could be transmitted from each transmitting antenna at a cell site depends on the number of radio channels (transmitters) that have been authorized. Typically, a maximum of 16 or 19 channels (depending on the system) could be used. Thus, for a typical cell site utilizing sector antennas, each of the three transmitting antennas could be connected to 16 or 19 transmitters for a total of 48 or 57 transmitters per site. When omnidirectional antennas are used, up to 96 transmitters could be implemented at a cell site, but this would be very unusual. While a typical base station could have as many as 48-57 transmitters, not all of the transmitters would be expected to operate simultaneously thus reducing overall emission levels.

Although the FCC permits an *effective* radiated power (ERP) of up to 500 watts per channel (depending on the tower height), the majority of cellular base stations in urban and suburban areas operate at an ERP of 100 watts per channel or less. An ERP of 100 watts corresponds to an *actual* radiated power of 5-10 watts, depending on the type of antenna used (ERP is not equivalent to the power that is radiated but is a measure of the directional characteristics of the antenna). As the capacity of a system is expanded by dividing cells, i.e., adding additional base stations, lower ERPs can be used. In urban areas, an ERP of 10 watts per channel or less is commonly used.

The signal from a cellular base station antenna is essentially directed toward the horizon in a relatively narrow beam in the vertical plane. For example, the radiation pattern for an omnidirectional antenna might be compared to a thin doughnut or pancake centered around the antenna while the pattern for a sector antenna is fan-shaped, like a wedge cut from a pie. As with all forms of electromagnetic energy, the power density from a cellular transmitter decreases rapidly (according to an inverse square law) as one moves away from the antenna. Consequently, normal ground-level exposure is much less than exposure very close to the actual antenna. Measurements made near typical cellular towers have shown that ground-level power densities are well below limits recommended by RF/microwave safety standards.

At a frequency of 869 MHz (the lowest base station frequency used), the 1982 RF protection guides of the American National Standards Institute (ANSI C95.1-1982), which has been used by the FCC and others, recommend that human exposure should be limited to a power density of about 2900 microwatts per square centimeter ($\mu W/cm^2$), as averaged over any six-minute period. This limit is many times greater than RF levels found near the base of typical cellular towers. Measurement data obtained from various sources have consistently indicated that "worst-case" ground-level power densities near typical cellular tower are on the order of 1 $\mu W/cm^2$ or less. Calculations corresponding to a "worst-case" situation (all transmitters operating simultaneously and continuously at the maximum licensed power) show that in order to be exposed to levels near the 1982 ANSI limits for cellular frequencies, an individual would essentially have to be in the main transmitting beam (at the height of the antenna) and within a few feet from the antenna. This makes it extremely unlikely that a member of the general public could be exposed to RF levels in excess of these guidelines.

Potential exposure can also be compared with the more restrictive limits recommended by the National Council on Radiation Protection and Measurements (NCRP), the International Radiation Protection Association (IRPA), or the Institute of Electrical and Electronics Engineers (IEEE). The IEEE guidelines (ANSI/IEEE C95.1-1992) have been recently adopted by ANSI to replace the 1982 guidelines mentioned above. The NCRP and ANSI/IEEE guidelines recommend a limit for exposure of the general public (or exposure in "uncontrolled" environments) of about 580 $\mu W/cm^2$ at 869 MHz. The corresponding IRPA recommendation is about 435 $\mu W/cm^2$. The exposure levels measured at ground level around typical cellular towers are hundreds or thousands of times lower than the above limits.

When cellular antennas are mounted at rooftop locations it is possible that RF levels greater than 1 $\mu W/cm^2$ could be present on the rooftop itself. This might become an issue if the rooftop were accessible to maintenance personnel or others. However, exposures approaching or exceeding the safety guidelines are only likely to be encountered very close to and directly in front of the antennas. Even if RF levels were to be higher than desirable on a rooftop, appropriate restrictions could be placed on access. Factoring in the time-averaging aspects of safety standards could also be used to reduce potential exposure. The fact that rooftop cellular antennas usually operate at lower power levels than antennas on free-standing towers makes excessive exposure conditions on rooftops even less likely and would not be expected to produce excessive exposure conditions for occupants within the building.

(2) <u>Mobile (vehicle-mounted) antennas</u>

Vehicle-mounted antennas used for cellular communications normally operate at a power level of 3 watts or less. These cellular antennas are typically mounted on the roof, on the trunk, or on the rear window of a car or truck. Studies have shown that in order to be exposed to RF levels that

approach the safety guidelines it would be necessary to remain very close to a vehicle-mounted cellular antenna. For example, a study done for AT&T Bell Laboratories by the University of Washington documented typical and "worst-case" exposure levels and specific absorption rates (SAR) for vehicle occupants and persons standing close to vehicle-mounted cellular antennas. Worst-case exposure conditions were considered when an individual was at the closest possible distance from the antenna. Several configurations were tested using adult and child "phantom" models.

The results of this study showed that the highest exposure (1900 μW/cm^2) occurred with a female model at a distance of 9.7 cm (3.8 inches) from one of the antennas operating with a power of 3 watts. Although this level approaches the ANSI protection guide for this frequency, the antenna could be driven to approximately 35 W of power before the 8 watts per kilogram (W/kg) partial-body threshold of the ANSI guidelines would be exceeded. The intermittent nature of transmission and the improbability that a person would remain so close to the antenna for any length of time further reduces the potential for excessive exposure.

The University of Washington study indicated that vehicle occupants are effectively shielded by the metal body. Also, Motorola, Inc., in comments filed with the FCC, has expressed the opinion that proper installation of a vehicle-mounted antenna to maximize the shielding effect is an effective way of limiting exposure. Motorola recommended installation either in the center of the roof or the center of the trunk. In response to concern expressed over the commonly-used rear-window mounted cellular antennas, Motorola recommended a minimum separation distance of 30-60 cm (1 -2 feet) to minimize exposure to vehicle occupants resulting from antenna mismatch for this type of antenna installation.

From data gathered to date, it appears that properly installed, vehicle-mounted, cellular transceivers using 3 watts of power would result in maximum exposure levels in or near the vehicle well below the safety limits recommended by ANSI or the NCRP. This assumes that the transmitting antenna is at least 15 cm (about 6 inches) or more from vehicle occupants. Time-averaging of exposure (usually a 6-30 minute period is specified) will usually result in still lower values when compared with safety guidelines.

(3) <u>Hand-held cellular telephones</u>

A question that often arises is whether there may be potential health risks to users of hand-held cellular telephones due to their exposure to radio waves used for cellular transmissions. The 1992 ANSI/IEEE and the NCRP guidelines contain exclusion clauses for hand-held RF devices that transmit at frequencies below 1000 MHz. These exclusion clauses are based on the belief that devices using power levels below the specified levels would not cause specific absorption rates (SAR) in excess of recommended limits. For example, the ANSI/IEEE partial-body limit in "controlled" environments is an absorption threshold of 8 watts/kg (W/kg) as measured over any one gram of tissue.

The NCRP recommendations dealing with localized power absorption are also based on a threshold of 8 W/kg, but only for occupational exposure. For the general population, a partial-body limit of one-fifth the occupational level, or 1.6 W/kg is recommended by the NCRP.

The 1992 ANSI/IEEE guidelines also recommend a 1.6 W/kg threshold for localized partial-body SAR in "uncontrolled environments." The ANSI/IEEE exclusion clause for hand-held RF devices in uncontrolled environments and for frequencies of 800-900 MHz is about 0.7-0.8 watts of

radiated power, slightly more than the maximum power of a hand-held cellular telephone. The power of a hand-held cellular telephone is controlled by the base station to operate at discrete power levels between 0.006 and 0.600 watts. The ANSI/IEEE exclusion clause thus implies that hand-held cellular telephones should not produce SARs that are in excess of the recommended limits for "uncontrolled" environments.

Measurements of SAR in models of the human head and other studies of SAR distribution have been reported using both "walkie-talkie" portable radios and hand-held cellular telephones. In general, these studies have shown that the 8W/kg limit recommended by ANSI and NCRP in occupational or "controlled" environments is unlikely to be exceeded by use of a radio operating at 800-900 MHz with power levels of up to several watts. In one of these studies it was shown that the 8 W/kg peak level might be exceeded for a hand-held "push to talk" radio operating at several watts if the antenna feed-point were located very close (1-2 cm or less) to the user's head or eyes. However, it was concluded that the guidelines would still likely be met because of the low duty factors associated with the use of this type of radio. The 1.6 W/kg threshold might be exceeded in the worst case, but when time-averaging is considered average exposure levels would likely be below recommended levels for low-powered hand-held radios.

For hand-held cellular telephones, although the duty factor (time the phone is actually transmitting in a given period) is likely to be higher than that for walkie-talkies, because the maximum power level is usually significantly lower (0.6 watts), exposure in excess of recommended guidelines is less likely. Studies of human head models using cellular telephones have generally reported that SAR values are below the 1.6 W/kg level as averaged over one gram of tissue. However, some recent studies have reported higher peak levels that suggest the need for further dosimetric studies.

Publicity over the issue of exposure to RF fields from cellular telephones has resulted in increased public concern. In response to this concern, an industry-sponsored group, Wireless Technology Research (WTR), has begun a multiple-year, multi-million dollar program to award grants to researchers who will investigate this issue. Persons interested in obtaining details about this program should contact the WTR at (202) 833-2800.

Another federal agency with regulatory authority over radiative emissions from cellular telephones is the U.S. Food and Drug Administration's Center for Devices and Radiological Health (CDRH). With regard to the possible health effects of exposure to RF fields from cellular telephones the FDA issued a "Talk Paper" in 1993. In this statement the FDA said that it did not have enough information at present to rule out the possibility of risk, but if such a risk exists "it is probably small." The FDA concluded that there is no proof that cellular telephones can be harmful, but if individuals remain concerned several precautionary actions could be taken. These included limiting conversations on hand-held cellular telephones to those that are essential and making greater use of telephones with vehicle-mounted antennas where there is a greater separation distance between the user and the radiating structure.

In addition to the FDA, the U.S. Environmental Protection Agency (EPA) has been investigating the issue of health effects of electromagnetic fields , including RF frequencies. The EPA has established a "hot line" for answering question from the public on this issue. The number is 1-800- 363-2383.

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